U.S. Naval Air Development Center

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Evaluation of the Ambient Noise Differential of the S2E and T-39 Series Aircraft

Weptask RAE 20J 043/2021/F012 10 11
Problem Assignment 043AE25-1

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DEPARTMENT OF THE NAVY
U. S. NAVAL AIR DEVELOPMENT CENTER
JOHNSVILLE
WARMINSTER, PA. 18974

Aerospace Medical Research Department

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SUMMARY

Pertinent data on the noise and vibration environments in the S2E and T-39 aircraft, supplied by the Advanced System Development and Structural Dynamics groups of North American Aviation, Inc. are presented and examined regarding the effects of the noise and vibration environments of these two aircraft on crew performance. The nature and scope of the effects of the acoustic noise and vibration environments on human performance are discussed. Both auditory and non-auditory effects are included, and particular emphasis is placed on the speech-interfering characteristics of the noise environment, and also its ability to cause permanent hearing loss. It was found that under some operating conditions the noise levels in the S2E were above specification limits, and that even with a protective helmet, the noise levels in the S2E were sufficiently high to cause some permanent hearing loss.

CONCLUSIONS

On the basis of the data available, specific conclusions can be drawn with respect to two items. The first is the fact that the pilot and co-pilot of the S2E face potential hearing loss over long periods of time if continually exposed to the noise levels which are present in the S2E cockpit. Second, noise levels in the S2E sometimes exceed not only the general noise level specification but its own detail specification as well. In the T-39D, the noise levels at no time exceed the DR criterion, and general specification levels are not exceeded. Assuming the noise level given in the detail specification for the S2E would apply with little or no modification to the T-39, there is no reason to believe that the mission would be affected adversely by the noise level present in the T-39 under conditions of normal search. Within the context of the data available, then, it would appear that the T-39 would provide an acoustic environment which is generally more satisfactory than that provided by the S2E.

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A. INTRODUCTION

The purpose of this report is to compare the acoustical and vibration environments of the S2E and the T-39/VS aircraft regarding their effects on crew performance. To this end, data were supplied by the Advanced System Development and Structural Dynamics groups of North American Aviation, Inc. taken during flights of an S2E and a T-39D, an earlier version of the T-39/VS. Correlative data on the environment of the S2E also were obtained from a report prepared by the U.S. Naval Air Test Center, Patuxent River, Md. where the preliminary electronic and electrical trials of the S2E were carried out.

This report begins by presenting some background material on the parameters of interest and outlining the criteria which are used in the evaluation of the data. As far as was possible, both direct and indirect effects of the noise and vibration environments are considered, including effects on the effectiveness of communication, likelihood of permanent hearing loss with repeated exposure, and effects on non-auditory performance. Conclusions are based only on the data provided, and subjective reports were not considered per se. It should be kept in mind that the indexes of noise effects reported here are probability statements only. These indexes are, in general, laboratory developments, and though sometimes validated by field study, their application to a specific operational situation for which normative data do not exist always carries with it some possibility of misinterpretation.

B. THE EFFECTS OF NOISE AND VIBRATION UPON PERFORMANCE

B.1. The Effects of Noise upon Non-Auditory Performance.

The body of research data relevant to this question is in general agreement that the presence of noise has little or no direct effect upon the performance of non-auditory tasks. In general, the findings indicate an initial decrement in performance when noise is first introduced into the performance situation. This initial decrement disappears as a result of a rapid adaptation to the noisy environment (Pollock and Bartlett, 1932; Hyman, 1950). Stevens, et al (1941) found little or no continuing effect of simulated aircraft noise upon selected motor coordination tasks, reaction times, and/or response to perceptual and mental tasks, even after exposures of as long as 7 hours a day for 4 weeks.

Though noise does not appear to exert an immediate influence upon task performance, indirect effects are quite likely as a result of the distracting annoyance and fatigue which may accompany exposure to noise. Hence, those non-auditory performance situations which could be considered most susceptible to noise degradation are those most affected by distraction in

general, i.e.,

"Tasks involving sustained attention and relatively long periods of time such as are involved in many dial or signal-monitoring situations, complex rather than simple tasks, and tasks in which the operator is paced by the system, particularly if the pacing is irregular (Morgan, et al, 1963, p. 475)."

The similarity between these task categories and the activities of the ASW crew member is immediately apparent. Thus noise constitutes a potential, though as yet unconfirmed, contributor to reduced efficiency in the airborne anti-submarine warfare situation.

B.2. The Effects of Noise Upon Auditory Performance.

Acoustic noise has, however, a direct effect on the efficiency of auditory performance. The effect of noise is manifested in several ways: (1) by masking the signal so that it will not be heard or received correctly, (2) by causing a temporary shift in the auditory threshold following the cessation of the noise, and in extreme cases, by (3) permanently altering the receptor so that its future capability for detecting the signal is diminished.

B.2.1. Speech Interference. One of the most common sets of conditions for auditory communication are those of speech in an environment of wide band continuous noise. Under these conditions a comparatively simple model of the behavior of the auditory system in response to speech signals (Beranek, 1947) will predict with fair accuracy the performance of a variety of communication systems in a variety of types of background noise. This prediction, termed the articulation index, indicates the intelligibility of a given message-set for a given talker-listener proficiency. It predicts the percentage of a given message-set which will be understood. The articulation index (AI) is determined from the signal-to-noise ratio averaged over 20 specified bands of frequencies within the speech frequency spectrum. To determine the articula tion index for a given situation, the measured spectral noise levels are superimposed on figure 1. This figure represents the sound pressure level of the slightly raised voice of a talker at a distance of 1 meter from the listener's ear. Speech at this level has, by definition, zero DB orthotelephonic gain. For conditions other than zero DB orthotelephonic gain, figure 2 indicates the amount by which the shaded portion of figure 1 must be raised or lowered when various conditions are present. The proportion of this shaded area left uncovered by the noise plot represents the articulation index. An AI of .3 is considered unsatisfactory, while one of .5 will, in general, be acceptable.

Certain modifications of this method will yield accurate AI's for a variety of conditions, including peak clipping, unusual vocal effort, and unsteady noise, which alter the masking effects of the noise (Kryter, 1960). A simplified method of calculating the AI by the use of octave bands is effective where the speech signal is relatively undistorted and when the noise is steady-state with no radical slopes in the spectrum (Kryter et al., 1961).

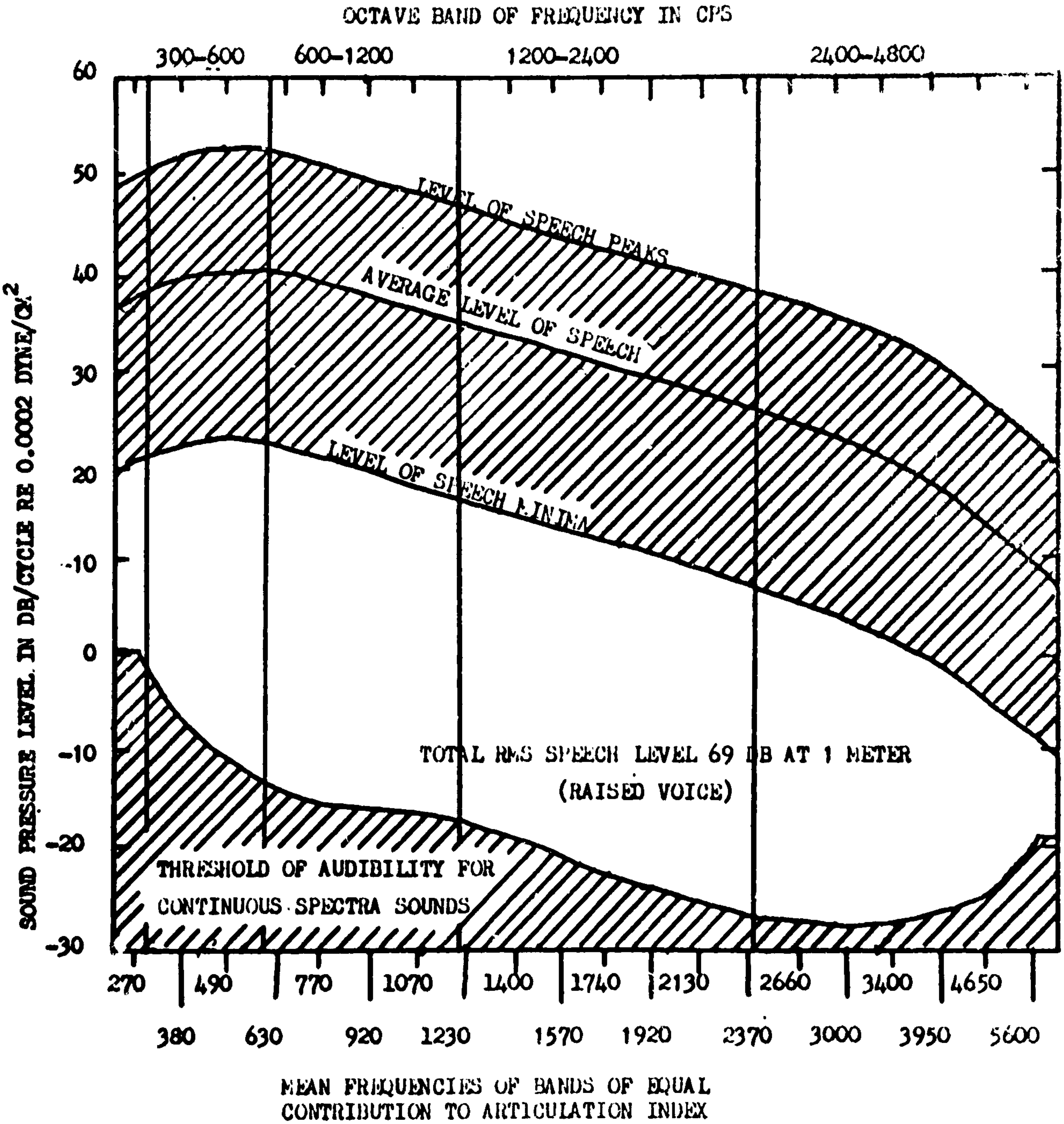

FIGURE 1

Chart for computing the articulation index for speech masked by continuous spectrum noise (Beranek, 1947)

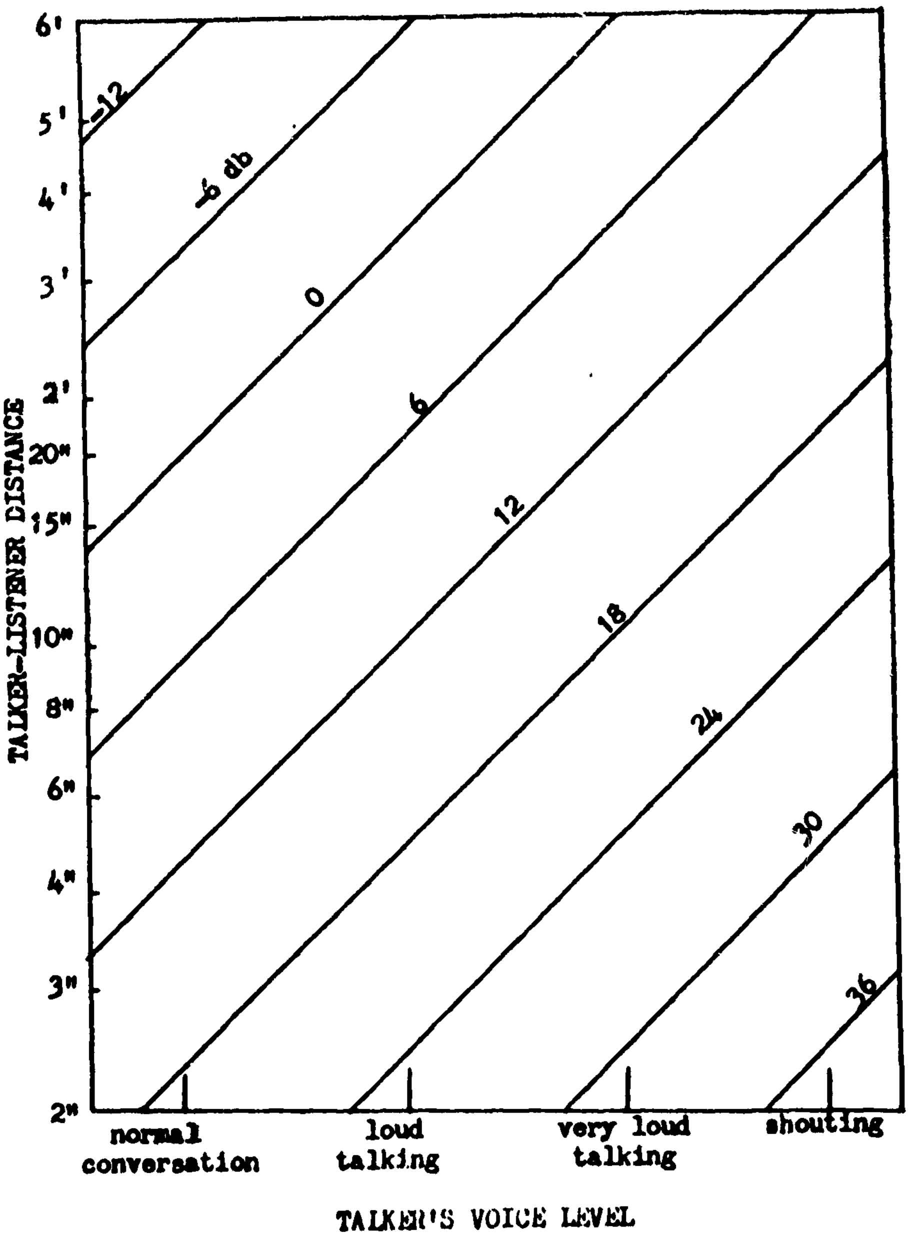

FIGURE 2

Chart for evaluating talker-listener distance and talker's voice level in terms of db shift of level at listener's ear

A measure which is related to the AI and which is a useful approximation to it is the speech interference level (SIL) which is the average, in decibels, of the sound pressure levels of the masking noise in the three octave bands of 600-1200 cps, 1200-2400 cps, and 2400-4800 cps. Strasberg (1952) has independently defined the SIL as the average of the sound pressure levels over the four octave bands of 300-600 cps, 600-1200 cps, 1200-2400 cps, and 2400-4800 cps. The speech interference level expresses the communication conditions for a selected degree of intelligibility that is marginal with conventional vocabulary and good with a selected (limited) vocabulary with respect to distance from talker to listener and voice level. The SIL concept was originally validated by studies using simulated noise from propeller-driven aircraft (Beranek, 1947).

The conditions under which the SIL is valid are the same as for the AI. Strasberg's method of measuring the SIL would appear to be preferred where low-frequency noise is present, as Miller (1947) has shown that if a low frequency noise (below 600 cps) is sufficiently intense, it can mask speech completely. Curves of equal speech interference based on Kryter's (1962) refinements of the articulation index show (Webster & Klumpp, 1963) that noise in the range 300 to 2400 cps is most efficient at masking speech. Physical measurements and calculations on differing noises having equal speech-interference show that the speech-interfering capability of a noise is best estimated by averaging the sound pressure levels in mid-frequency octaves, then by use of frequency-weighting networks in sound-level meters, and finally by fitting the spectral peaks to noise contours. More specifically, the best of the SIL methods, the 300-2400 cps SIL calculation, gave slightly better predictions than any other combination of octaves.

Also of interest is the way in which the most critical frequencies for hearing of speech vary with the intensity of the speech. Thus, when the level is raised high enough for an articulation index of 1.00 (i.e., for perfect hearing of speech) 3000 cps is the most important frequency, while for the speech reception threshold, which means a 50% score and is equivalent to an Articulation Index of 0.3, the most important frequency is 1000 cps. With lower articulation indexes still, the important frequency falls as low as 700 cps.

B.2.2 Hearing Loss. Hearing loss can be a result either of some degeneration of the sensory cells of the inner ear or the auditory nerve, or of damage to the ossicular chain or the eardrum. The former type, called perceptive hearing loss or nerve deafness, results in different degrees of loss for differing frequencies, usually affecting the high frequencies to the greatest degree. Normal deterioration of hearing in aging is usually of this type. The latter type is known as conduction deafness, and is characterized by a pure-tone hearing loss that is the same order of magnitude at all frequencies.

The effects of conduction deafness are limited by the fact that sound is transmitted through the bones of the head in addition to the air conduction pathway which may be disrupted.

B.2.2.1. Temporary Hearing Loss. A sound of almost any intensity will give rise to a shift in the auditory threshold. The degree and duration of this shift is of course dependent on the characteristics of the sound. Regarded simply, this threshold shift is merely the mechanism of adaptation, by which the organism defends itself against its environment: the response to any continued stimulus decreases after the initial response burst. Munson and Gardner (1950) have discussed short-term auditory fatigue in terms of the concept of residual masking. The phenomenon of masking has been extensivel studied in terms of type of signal, type of noise, phase relationships, and othe parameters. The masking of speech by broad band noise, which is of present concern, is of course described by the articulation index and speech interference level. However, quantitative measurement of residual masking invol certain additional variables. Ward, Glorig, and Sklar (1958, 1959a, 1959b) have done considerable work in the area of residual masking, and have found that dependence exists among exposure time, sound pressure level, and proportion of time the noise is present. They found, for example, that the temporary threshold shift (TTS) for pure tones caused by a given octave band noise pattern was related in the following manner:

$$TTS = k(SPL-SPL_o) \ [\log (T/T_o)] + C$$

where k, SPL_o, T_o, and C are constants for the given stimulus and SPL and T parameters of exposure. For the effects of combinations of stimuli, it is possible to add the intensities of the shifted thresholds with the total TTS the $\log_{10}$ of the sum of the antilogs of the TTS due to each noise.

A value which is easier to measure than the TTS present immediatel after exposure is the threshold shift measured two minutes after the cessation of the noise. This quantity is designated TTS_2. As might be expected, it has been shown (Ward , Glorig & Sklar, 1959b) that lower values of TTS_2 require less time for recovery than larger values. The course of recovery from TTS is independent of the manner of production of TTS, except insofar as these parameters determine TTS_2. Unfortunately at this time it is not possible to predict accurately the degree of permanent hearing loss which will be likely to occur when there is a given TTS or TTS_2. It has been suggested (Ward, Glorig & Sklar, 1959a) that a TTS of 40 db might lead to some permanent impairment if the noise causing it were continuous over an eight hour period.

B.2.2.2 Permanent Hearing Loss. There is a considerable body of evidence to the effect that long exposure to high noise levels contributes to hearing loss (Berrien, 1946, Kryter, 1950, McCord et al, 1938, McElvie, 1933, MacLaren & Chaney, 1947). This hearing loss is the type of permanent nerve deafness that represents a significant change in the normal pattern of hearing impairment which occurs with age, and is frequently exhibited by persons who are occupationally exposed to high intensity noise.

As in other acoustic areas, the parameters underlying hearing loss are numerous. Other things being equal, the more intense the noise the greater the likelihood of permanent hearing loss. Hearing loss also depends on frequency of the noise and duration of exposure. In addition, there is evidence that the intermittency of the noise and its impulsive character also are important. Of course, of primary importance is the question of how much hearing loss represents significant damage and how it is to be measured. The emphasis in determining safe sound levels has been in the area of long term exposure to steady state wide band noise; however, other conditions have been studied and it is possible to specify safe levels for these conditions, at least to some degree.

The object in this area is the development of a damage risk (DR) criterion which specifies safe levels at various frequencies for wide band noise, pure tones, or critical bands. Kryter (1950) suggested that for intermittent exposures of long duration, any sound frequency that is 85 db or less above 0.0002 dyne/cm^2 will cause no permanent or temporary deafness. Above this level it was surmised that repeated intermittent exposure over several years might cause some deafness. For brief exposures, sound pressure levels up to 100 db may be considered safe. Using these statements of risk as a starting point, Rosenblith and Stevens (1953) developed a DR criterion which also took into account the fact that exposure to any perceptible noise would produce some temporary deafness (adaptation). Their criterion also incorporated evidence from field studies which indicate that noise in which the energy is concentrated below 300 cps is less effective in producing permanent hearing loss than noise of equal sound pressure level in the middle frequencies with a marked sensitivity to hearing loss in the region between 1200 and 4800 cps. The DR criterion curve developed takes these factors into account, and also reflects the data which show that octave bands of noise and pure tones within the octave are equally effective in producing hearing loss, providing they have the same SPL. Figure 3 presents the DR criterion for exposures to noise with a reasonable continuous time character with no substantial sharp energy peaks over a period of working days up to a lifetime. Sound pressure levels below the DR curve will be unlikely to cause permanent hearing loss, while levels 10 db above the curve will probably cause extensive hearing loss.

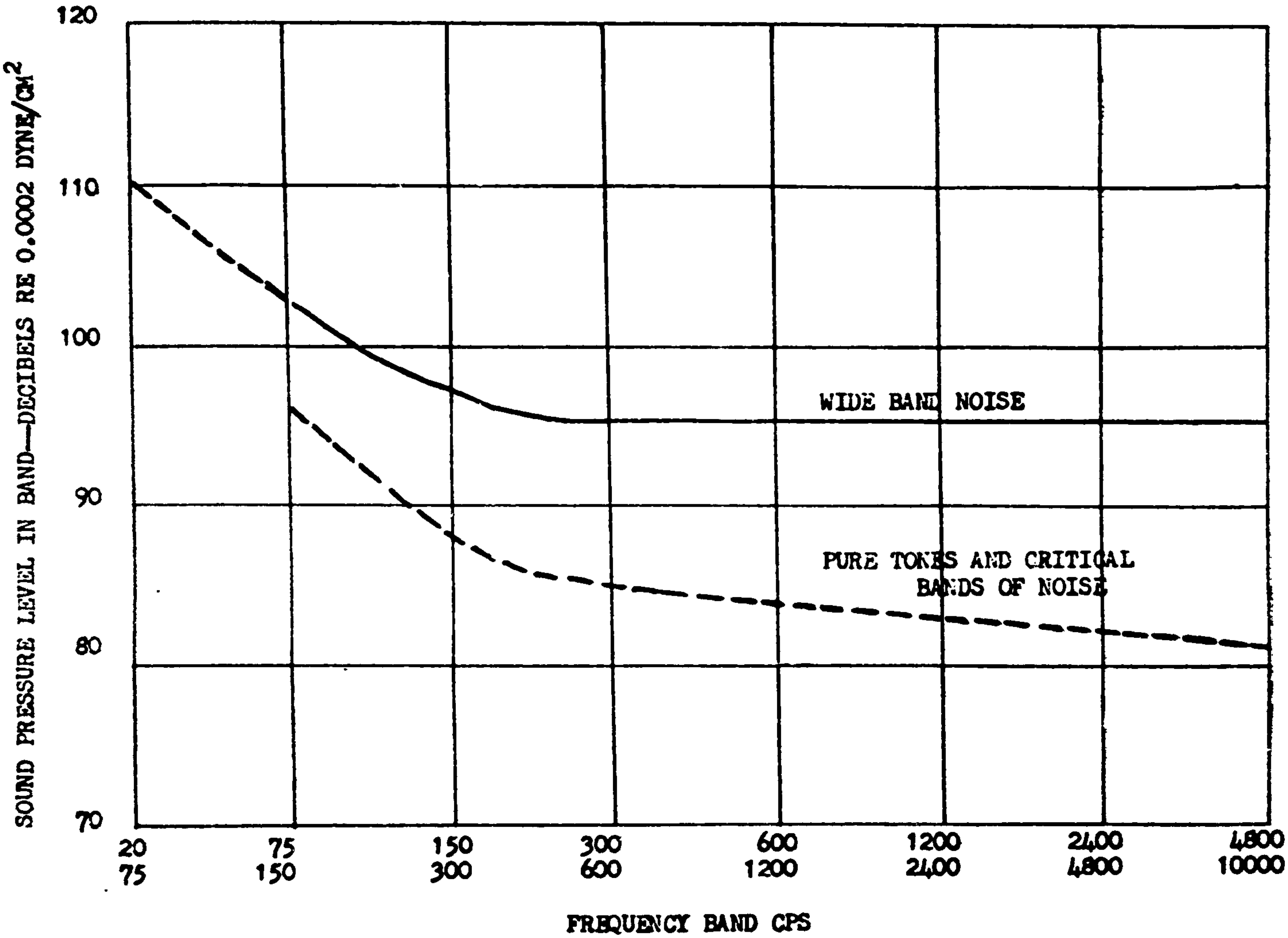

FIGURE 3

Damage risk criterion for wide-band noise and pure tones for lifetime exposure

B.2.3. Attenuation Effect of Helmet Use. In aircraft where protective helmets are worn and where communication is accomplished by electronic means, the ambient noise level will be attenuated by the helmet. In addition, the gain of an electronic communication system can be increased to the point where the signal-to-noise ratio will permit satisfactory communication in the presence of high ambient noise levels.

In determining the effect of wearing a helmet, the sound attenuation afforded by the helmet throughout the sound spectrum must be determined, and the ambient noise spectrum diminished by this amount. A representative helmet is the type APH-5, for which the sound attenuation characteristics have been determined (NAMC, 1955). These characteristics are presented in figure 4. It should be noted that the helmet provides minimal attenuation in the region of 100 cps; the frequency range in which aircraft noise levels are the highest. It should also be noted, however, that with respect to the DR criterion the safe noise level is higher at this end of the spectrum than at the higher frequencies.

B.3. The Effects of Vibration.

Vibration affects human performance when the vibratory forces displace or damage organs or tissues other than those ordinarily concerned with hearing or when they produce perceptible pain, annoyance, or fatigue. The vibrations which ordinarily produce these effects have high amplitude and are of low frequency. Vibration amplitudes in aircraft depend generally on the power of the propulsion system and on aerodynamic forces. The energies of vibrations from vehicle sources are most important to man in the range from 2 to 20 cps (Goldman & Von Gierke, 1960). Various parts of the body have different resonant frequencies, and the body as a whole appears to respond to different components of the vibration at differing frequencies. Between 1 and 6 cps the body responds primarily to the jolt component, between 6 and 9 to the acceleration, and between 9 and 250 cps the primary response is to the maximum velocity imparted by the vibration. The vibration damping characteristics of the human body itself must be taken into account when examining vibration data pertaining to structures. For example, a human in the seated or standing position on a vertically vibrating table will experience whole-body resonance at about 5 cps, at which point the accelerations of various parts of his body will exceed the accelerations of the table. As the frequency is raised, the body accelerations diminish, until at 30 or 40 cps they are only about 30% of the table accelerations. For lateral vibration, the accelerations are damped at even lower frequencies.

The vibration amplitude threshold varies with frequency. Between 100 and 500 cycles per second the threshold is as low as 0.00004 inches, whereas below 60 cps and above 1000 cps the threshold rises to about 0.00015 inches.

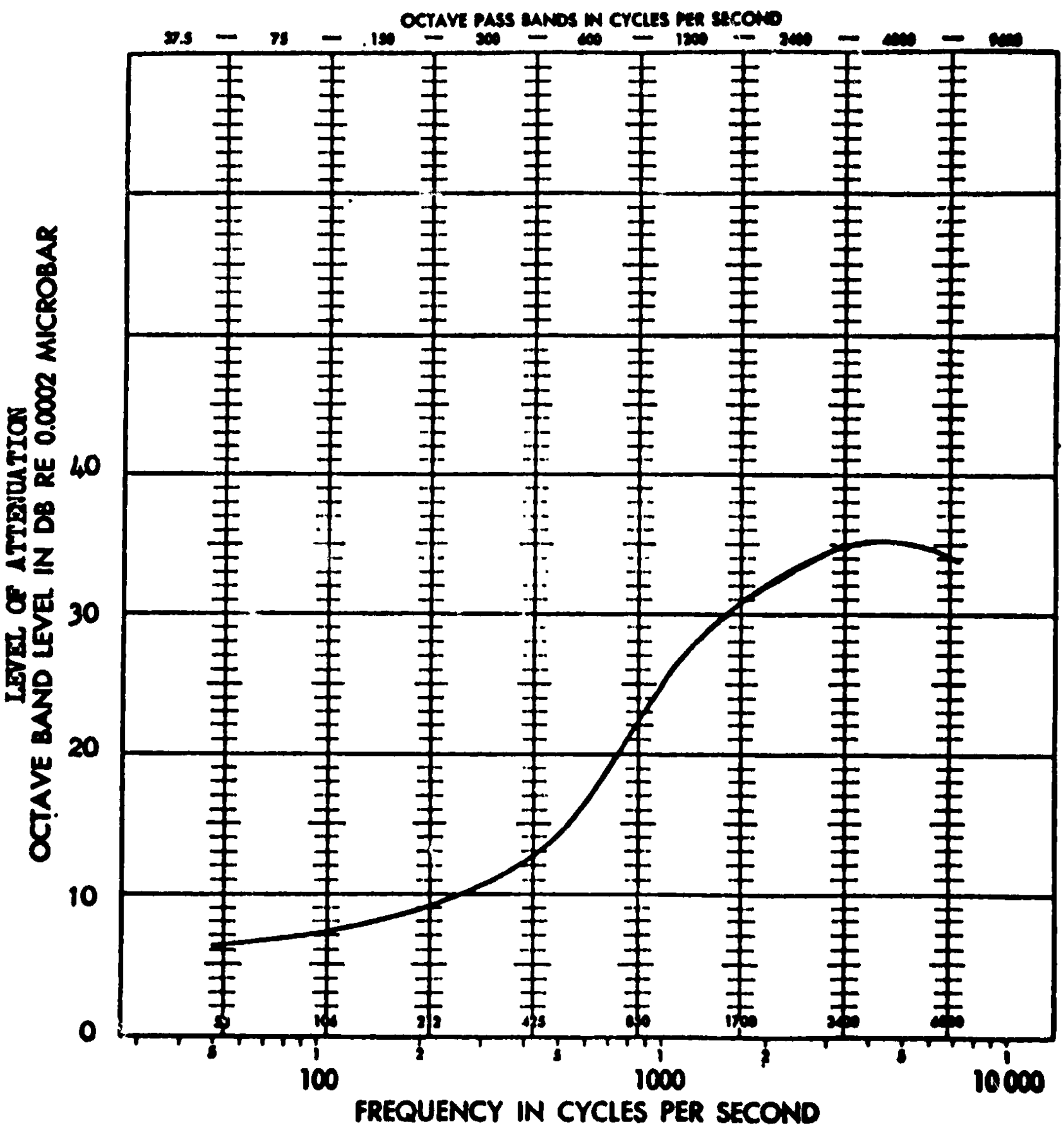

FIGURE 4

Sound-attenuating characteristics of the APH-5 protective flying helmet (NAMC, 1955)

Over most of the frequency range the limit of vibration tolerance is from 15 to 20 times the threshold amplitude. The limit of tolerance based on data from Woodson (1954) and Chaney (1964) is indicated in figure 5 in terms of acceleration and frequency. With increasing frequency, the tolerable acceleration levels also increase, as the duration of the acceleration is reduced.

C. COMPARISON OF THE S2E AND T-39 AIRCRAFT

C.1. Vibration Comparison.

C.1.1. Vibration levels in the T-39. Vibration levels in terms of accelerations were measured at several frequencies from 96 cps to 1468 cps at three points in the aircraft, two on the basic structure and one on the control column. The vibration measurements on the structure were of vertical vibration and on the control column were of horizontal vibration. The vibration levels from a representative position (floor near left hand student console) are plotted on figure 5. They are within the tolerable region for all measured frequencies. Unfortunately, data are not available for the frequency range which most affects human performance, that is, the range below 20 cps. Hence, it is impossible to state definitely whether or not the vibration levels in the T-39 will have any effect on mission performance.

C.1.2. Vibration levels in the S2E. The vibration data received for the S2E give only maximum amplitudes and no indication of the frequencies at which the reported amplitudes occurred. It is possible that these maximum amplitudes were isolated peaks. Therefore, no conclusions related to the vibration environment of the S2E can be drawn. It is expected that vibration levels would be higher for the S2E than for the T-39, but it is not possible to determine from the available information whether there would be any adverse effects on performance due to the vibration in the S2E.

C.2. Noise Levels of the S2E and T-39D Aircraft.

For the purpose of comparison of the two types of aircraft, sound level measurements were made at several different locations in each aircraft under varying operating conditions. In each case measurements were made of the overall sound level and of octave band levels within the sound spectrum. The octaves measured in the S2E were 37.5-75, 75-150, 150-300, 300-600, 600-1200, 1200-2400, 2400-4800, and 4300-9600 cycles per second. In the T-39D tests, no measurements were made of the 4800-9600 cps octave, otherwise, comparable octaves were measured in both aircraft. It is not

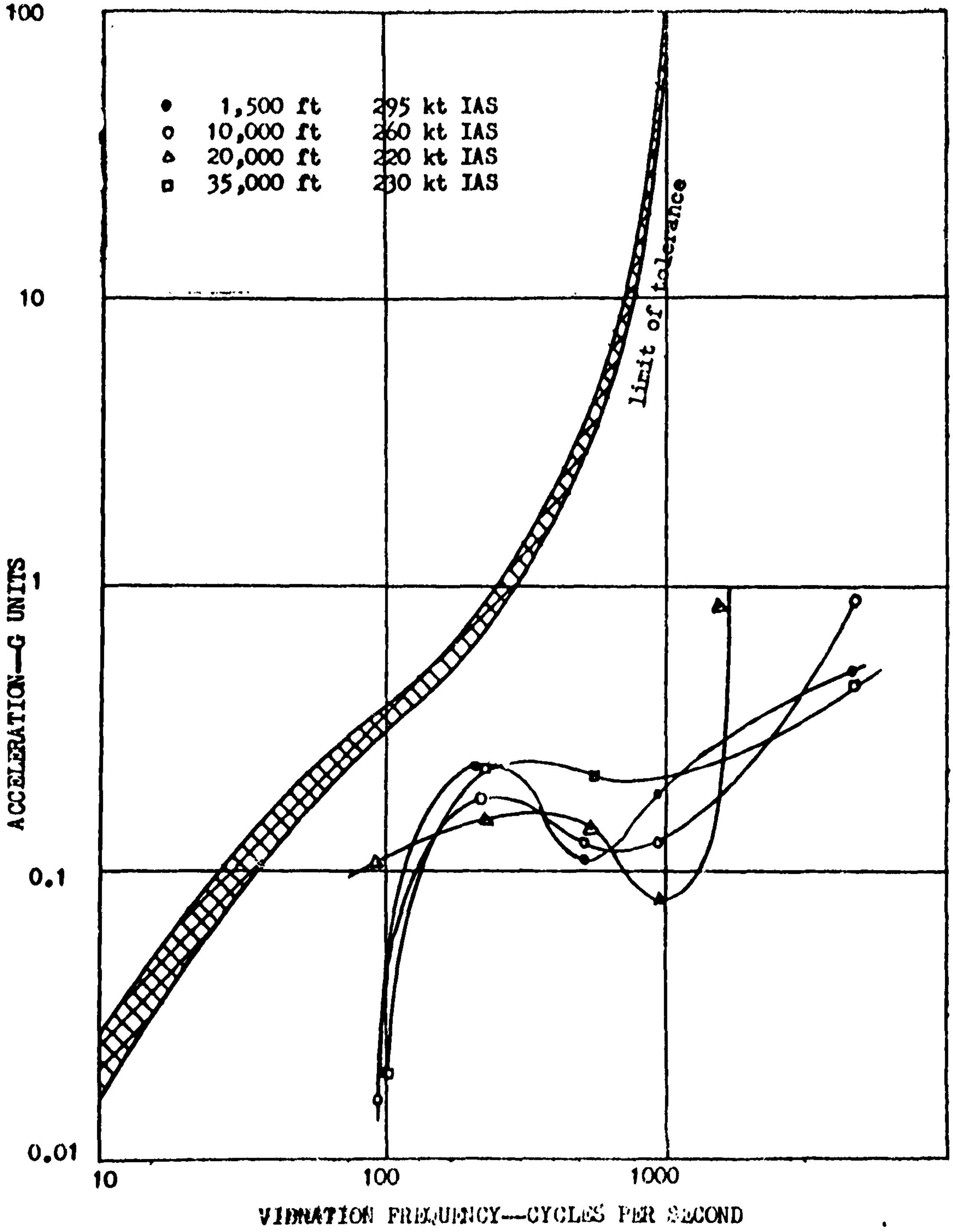

FIGURE 5

Vibration levels in the T-39D aircraft as measured under several different operating conditions.

expected that omission of measureme ts in the highest octave band in the T-39D tests would alter the results of the comparison, especially in terms of speech interference. However, sound levels at higher frequencies are relatively greater in jet than in propeller driven aircraft. In addition, deviations from level flight in jet aircraft result in sound levels which are increased over levels present in level flight. These increases are most notable in the higher frequencies (Franken, Kerwin, et al., 1958).

Although sound pressure level measurements were taken at several locations and under several different operating conditions in each aircraft, these locations and conditions were not always comparable. Therefore, the comparison of acoustic environments was based upon the range of both overall and octave band levels across all conditions at each of two comparable positions: (1) in the cockpit at the outboard ear of either the pilot or copilot, and (2) the middle of the aft area of the cabin. Sound levels in the two aircraft for the cockpit and the cabin positions are plotted in figures 6 and 7 respectively.

It is evident from figures 6 and 7 that the sound levels in the S2E are generally higher than those in the T-39D. It is necessary, however, to determine whether the difference in levels is significant from the standpoint of crew performance.

First, the effect of high ambient noise levels on auditory communication must be considered. In this respect there are two distinct situations, one in which a protective helmet is worn and communication is effected by electronic means, and the other in which no helmet is worn. If no helmet is worn but communication is by electronic means and sound attenuating headphones are worn, the ambient noise will be attenuated to approximately the same degree as when a helmet is worn (Morgan, et al, 1963). If no helmet is worn, the ambient noise is not attenuated and directly affects voice communication. It is clear that communication would be difficult under such conditions in the aircraft in question. To determine the degree of communication which is possible in the S2E and the T-39D without an electronic system, the SIL can be used. Calculation of the range of the SIL for the two positions in each aircraft by the method suggested by Strasberg (1952) yields the result shown in Table I. Table 2 (from Beranek, 1947) gives the conditions under which reliable conversation can barely be carried on for a range of SIL's. It is apparent that, in either aircraft, communicating without an electronic intercom system is virtually impossible in some cases, and difficult at best. Table 2 is comparable to a relation given by Rosenblith and Stevens (1953) which states that for a SIL of 75 minimal communication, with a restricted prearranged vocabulary of danger signals only, can be carried out with a very loud voice at a talker-listener distance of one foot or by shouting at two or three feet.

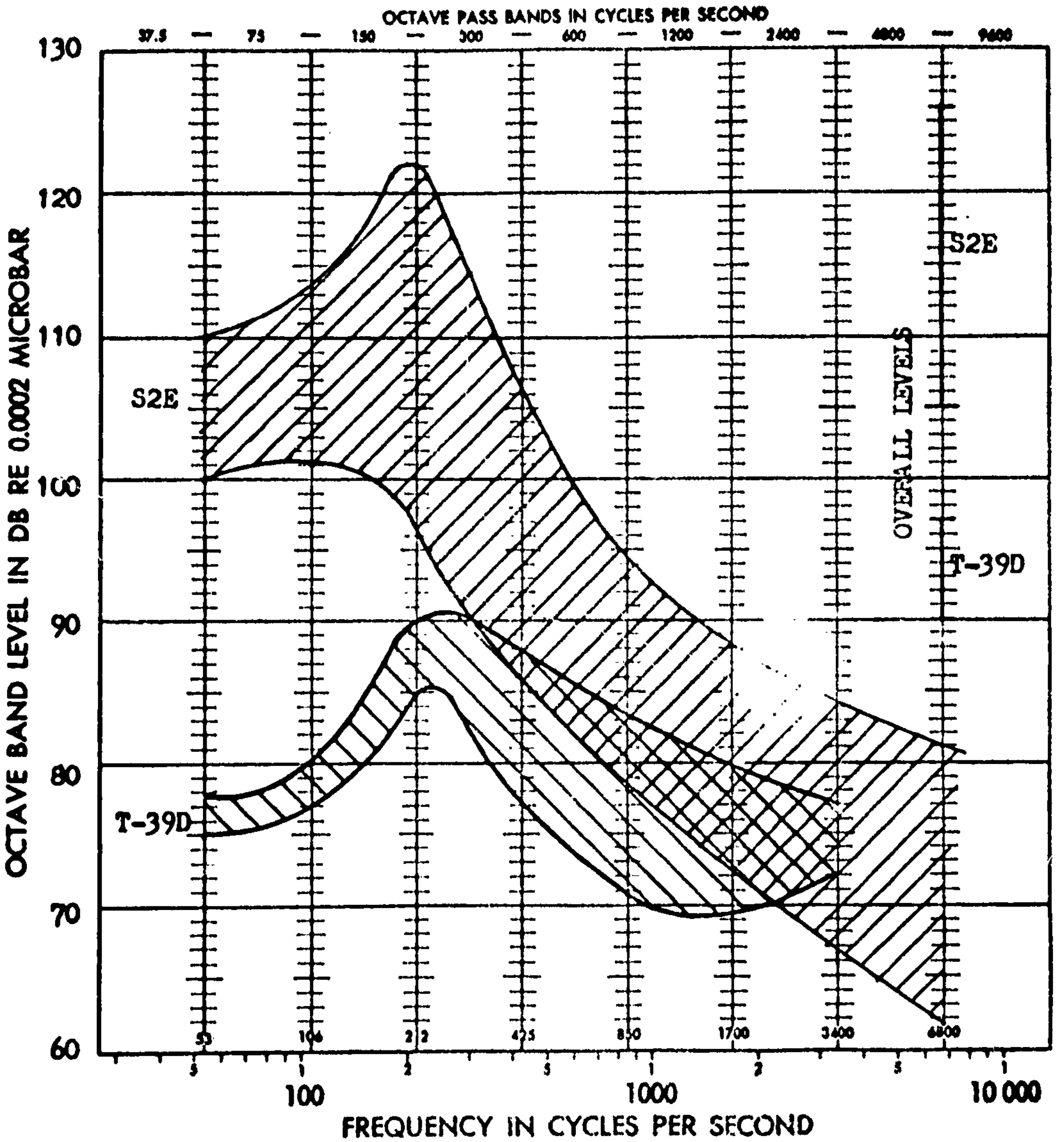

FIGURE 6

Range of ambient sound pressure levels measured
in the cockpit of the S2E and T-39D

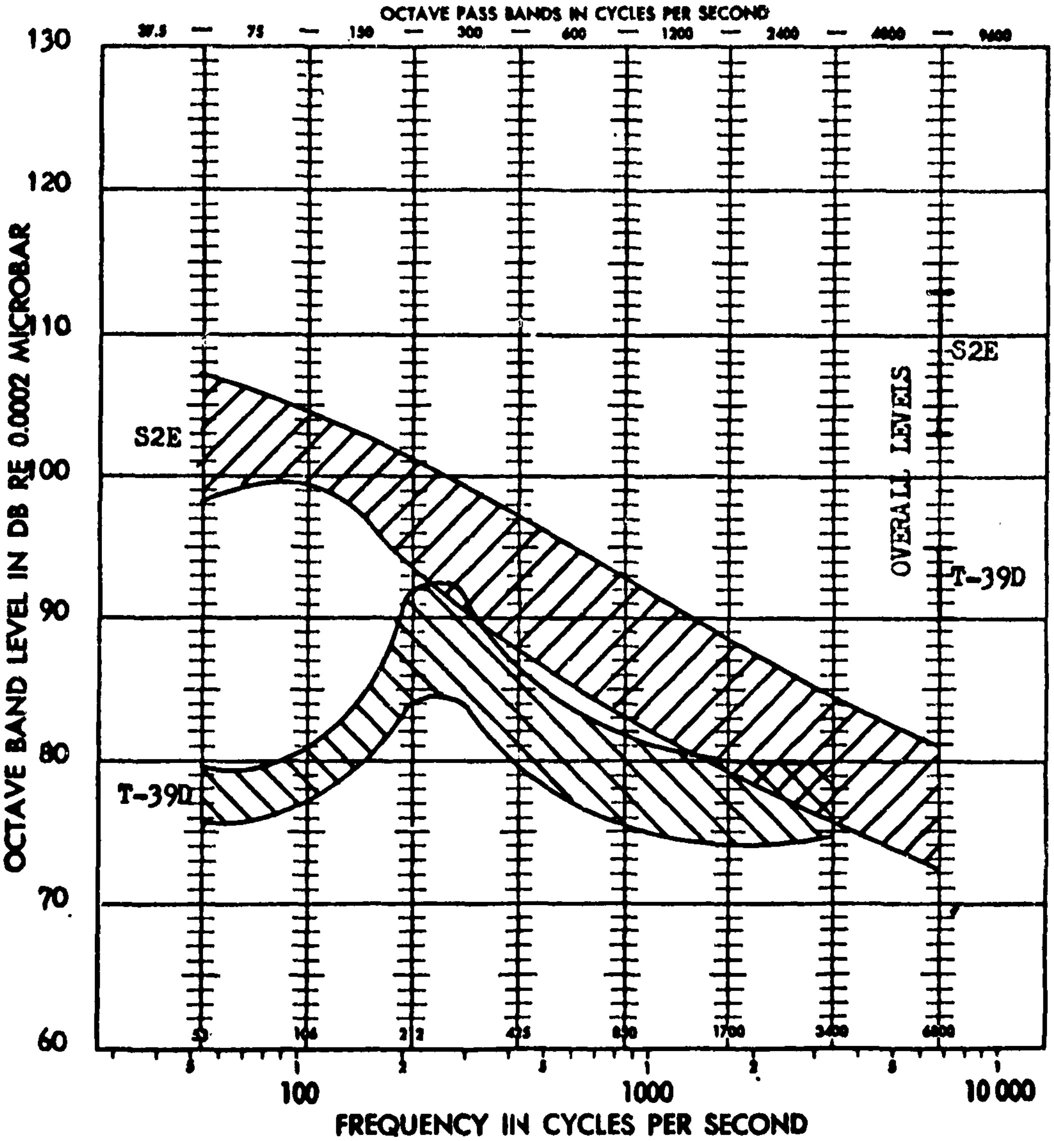

FIGURE 7

Range of ambient sound pressure levels measured in the cabin of the S2E and T-39D

TABLE 1

Speech Interference Levels in the S2E and T-39D Aircraft, Calculated by the Method of Strasberg (1952)

Aircraft Type	Location	SIL(db)	
		Low	High
S2E	Cockpit	76	93
T-39D	Cockpit	72	82
S2E	Cabin	81	91
T-39D	Cabin	76	82

TABLE 2

Speech Interference Levels (In db re 0.0002 dyne/cm^2) which barely permit reliable conversation at the distances and voice levels indicated (from Beranek, 1947)

Voice Level / Distance (Ft)	Normal	Raised	Very Loud	Shouting
0.5	71	77	83	89
1	65	71	77	83
2	59	65	71	77
3	55	61	67	73
4	53	59	65	71
5	51	57	63	69
6	49	55	61	67
12	43	49	55	61

Where a helmet is worn, the problem changes, as there is some attenuation of the ambient noise and amplification of the voice is possible. There is no doubt that satisfactory communication can be achieved under these conditions, if the level of speech is sufficiently high. Figure 8 shows the sound pressure level of normal speech at a talker-listener distance of 1 meter. Also shown in this figure is the speech curve when raised by electronic means to the level just below the damage risk area. It should be noted that the frequency range of communication systems normally used in aircraft is from 300 to 4000 cps, and that frequencies outside this range contribute little to intelligibility.

If figure 8 is superimposed on figure 9 which shows the range of sound pressure levels in the cockpit of the S2E reduced by the amount which is due to helmet attenuation, it can be seen that while speech at a normal level falls largely within the range of ambient sound levels, amplified speech which is still below the damage risk area is almost entirely above the ambient sound level curve. Calculation of the articulation index for the latter condition yields a value of .78, a figure which represents a very satisfactory level of communication. If this procedure were repeated with figure 10, which shows the attenuated ambient levels for the T-39D cockpit, an even higher AI would be obtained.

Consideration must also be given to the possible effects of the ambient noise levels of the two aircraft on the auditory acuity of the crews. In this respect, figures 9 and 10 can be considered as representing the protection against the ambient noise levels afforded by some type of protective helmet or sound-attenuating earphones. The DR criterion previously discussed is shown on each figure. It can be seen that even with a helmet, the noise levels in the S2E cockpit exceed the DR criterion under some of the operating conditions tested. The noise levels in the S2E without a helmet are of course even further above the DR criterion. The noise levels in the T-39D at no time exceed the DR criterion, either with or without a helmet.

D. DISCUSSION

In evaluating the effects of the acoustic environment on crew performance, it is possible to draw certain conclusions based on measured noise levels. However, there are certain other factors which may affect performance, and these also must be considered. In this section the available information will be presented as a basis for any conclusions which may be drawn.

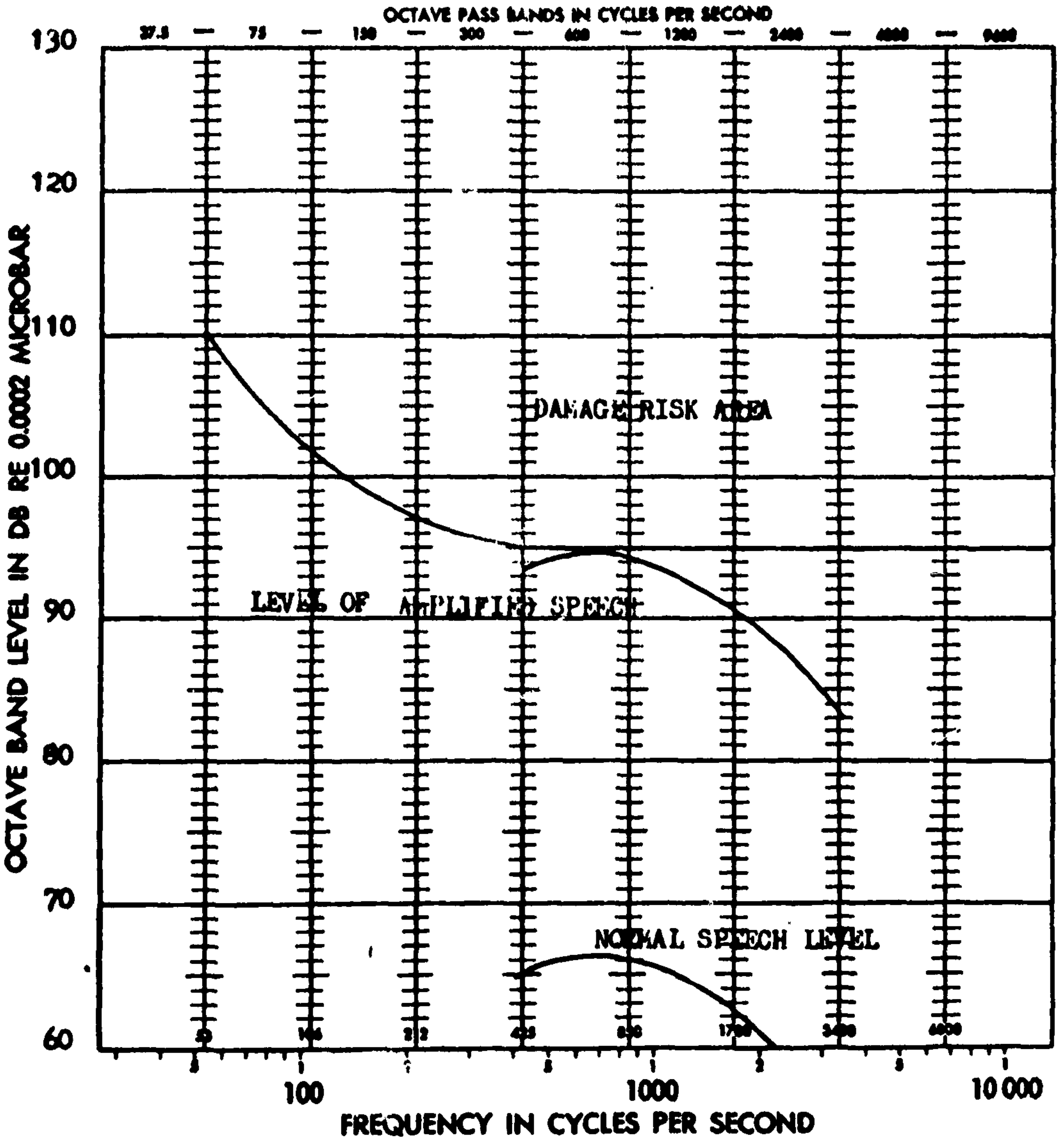

FIGURE 8

Sound pressure levels of normal speech and electronically amplified speech which remains below damage risk area

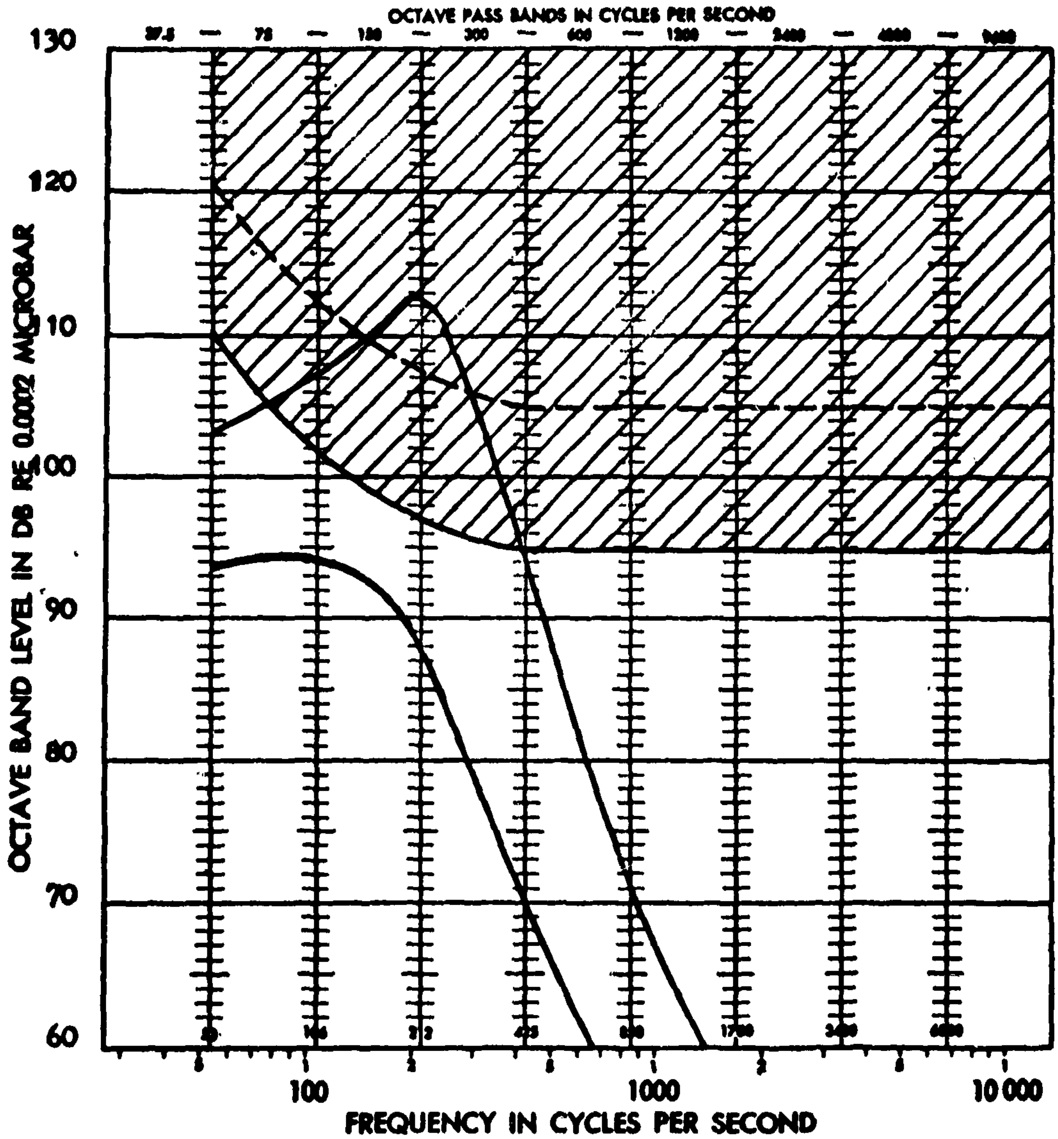

FIGURE 9

Sound pressure levels of S2E cockpit corrected for helmet attenuation, showing DR area

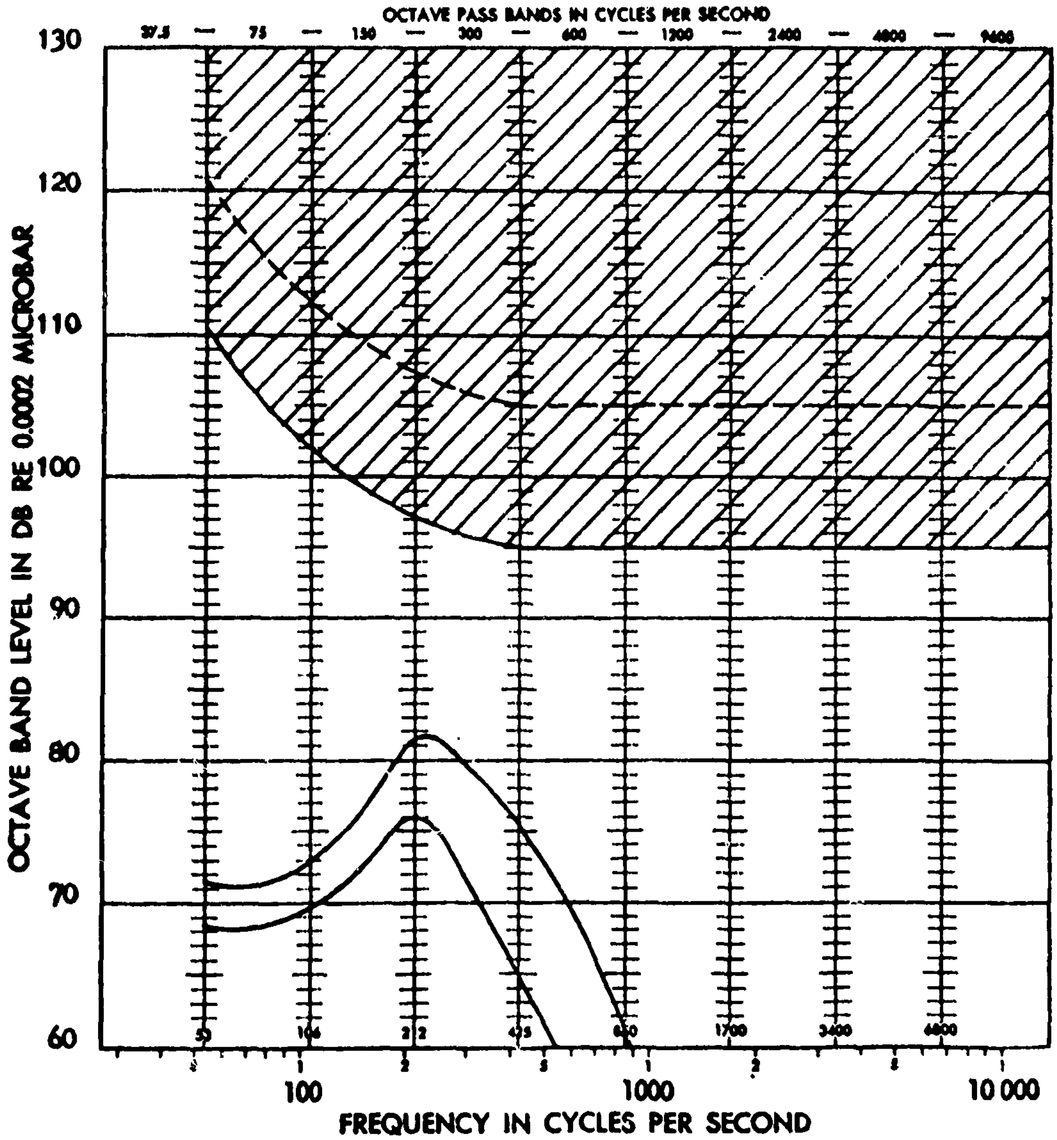

FIGURE 10

Sound pressure levels of the T-39D cockpit corrected for helmet attenuation, showing DR area

For carrier-based ASW use, the crew of the T-39 will wear protective helmets as does the crew of the S2E. Under these conditions voice communication can be carried on satisfactorily, due to the attenuation afforded by the helmet and the increased voice levels possible with an electronic communications system. Without helmets, there are some conditions in which communication would not be possible in either aircraft.

The sound protection provided by a helmet is not sufficient in the S2E to lower the sound pressure level in the cockpit area so that it is always below the level at which damage could be expected with repeated exposure.

Noise levels in the S2E, particularly the overall levels and levels at the lower frequencies exceed the limits set forth in the General Specification for Acoustical Noise Level in Aircraft, Military Specification MIL-A-8806 (ASG). These excessive noise levels are in general confined to the cockpit.

The detail specification for the S2E (1957) sets forth maximum noise levels for the sonobuoy (#4 operator) station under conditions of normal search. These levels are represented by the heavy line in figure 11. Also on this figure are lines showing noise levels for this location and operating condition for the S2E as tested by NAA and also by NATC, and for the T-39D. It can be seen that the S2E as tested by NAA exceeds specification levels in all octave bands. The data from the NATC test are included for comparison. It should be noted that these data were taken with a different instrument, and although the variation between any two instruments should be minimal, primary consideration will be given to the NAA data, all of which (both for the S2E and T-39D) were taken with the same instrument. The noise level in the T-39D is below the specified limit up to about 3000 cps, and then rises to levels above specification.

There are other factors influencing crew performance which cannot be described, as yet, in quantitative terms. One of these is the effect of high ambient noise levels on non-auditory performance. As discussed in Section B.1, it is possible that high noise levels may be particularly detrimental to the performance of missions with the characteristics of ASW missions. Another factor is the temporary threshold shift which occurs during and following noise exposure. At this time, the effects of noise on the hearing threshold have been measured only for specific conditions, and the relationships developed require detailed specifications of conditions in order to obtain valid results. It is obvious that over the course of a long mission, this task would be virtually impossible since different operating conditions are encountered at varying intervals, in different sequences, and for differential lengths of time. It is

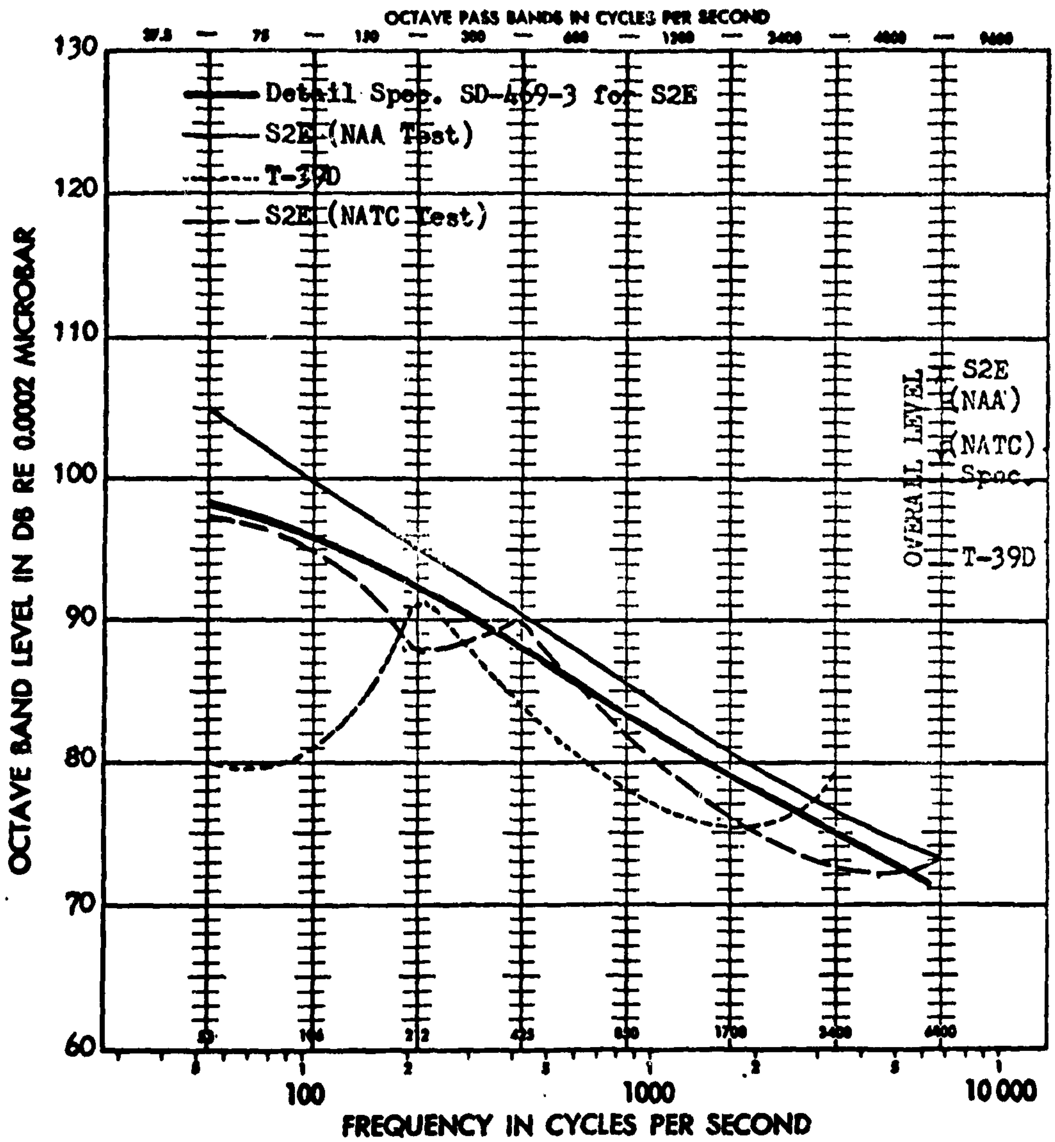

FIGURE 11

Sound pressure levels at sonobuoy operator station in S2E and T-39D compared to S2E detail specification of sound pressure level

For carrier-based ASW use, the crew of the T-39 will wear protective helmets as does the crew of the S2E. Under these conditions voice communication can be carried on satisfactorily, due to the attenuation afforded by the helmet and the increased voice levels possible with an electronic communications system. Without helmets, there are some conditions in which communication would not be possible in either aircraft.

The sound protection provided by a helmet is not sufficient in the S2E to lower the sound pressure level in the cockpit area so that it is always below the level at which damage could be expected with repeated exposure.

Noise levels in the S2E, particularly the overall levels and levels at the lower frequencies exceed the limits set forth in the General Specification for Acoustical Noise Level in Aircraft, Military Specification MIL-A-8806 (ASG). These excessive noise levels are in general confined to the cockpit.

The detail specification for the S2E (1957) sets forth maximum noise levels for the sonobuoy (#4 operator) station under conditions of normal search. These levels are represented by the heavy line in figure 11. Also on this figure are lines showing noise levels for this location and operating condition for the S2E as tested by NAA and also by NATC, and for the T-39D. It can be seen that the S2E as tested by NAA exceeds specification levels in all octave bands. The data from the NATC test are included for comparison. It should be noted that these data were taken with a different instrument, and although the variation between any two instruments should be minimal, primary consideration will be given to the NAA data, all of which (both for the S2E and T-39D) were taken with the same instrument. The noise level in the T-39D is below the specified limit up to about 3000 cps, and then rises to levels above specification.

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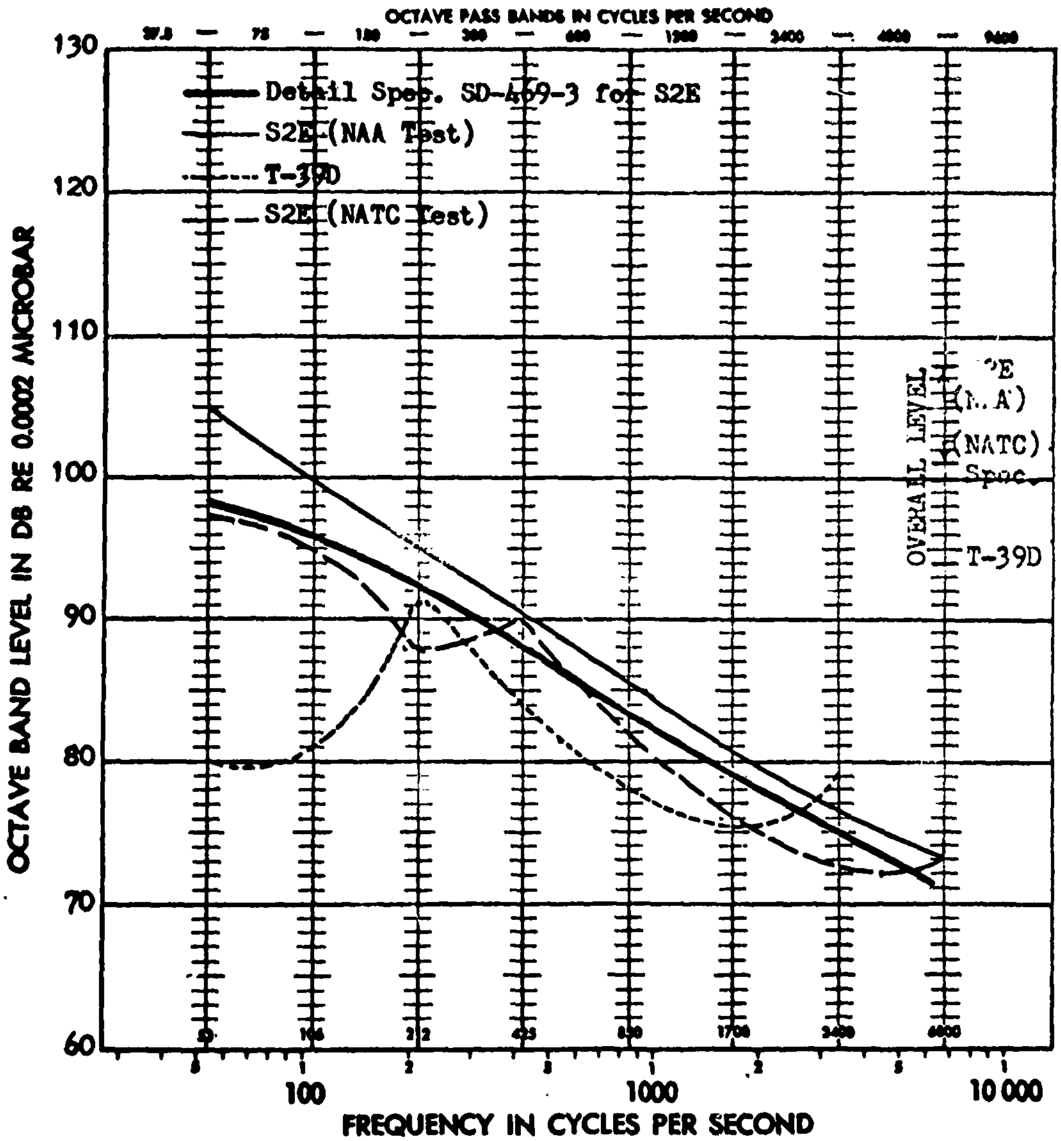

FIGURE 11

Sound pressure levels at sonobuoy operator station in S2E and T-39D compared to S2E detail specification of sound pressure level

possible that a given threshold shift would be more critical at one phase of the mission than at any other. It can only be assumed that low levels of ambient noise are more desirable than high ones. For the factors just mentioned, however, there is no evidence that performance is significantly affected by the noise level.

REFERENCES

Beranek, L. L. The design of speech communication systems. Proc. I.R.E., 1947, 35, 880-890.

Berrien, F. K. The effects of noise. Psychol. Bull., 1946, 43, 141-161.

Chaney, R. E. Subjective reaction to whole-body vibration. Contract Nonr-2994 (00), Research on Low Frequency Vibration Effects on Human Performance. Boeing Co., Report No. D3-6474, Sept. 1964.

Department of the Navy, Bureau of Aeronautics. Detail Specification for Model S2F-3 anti-submarine warfare carrier-based landplane four-place twin engine class VS. SD-469-3, 1957.

Franken, P. A., and Kerwin, E. M., Jr. Methods of Flight Vehicle Noise Prediction. Aircraft Laboratory, Wright Air Development Center, Air Research and Development Command, USAF, Wright-Patterson AFB, Ohio. WADC TR 58-343. November, 1958.

Goldman, D. E., and Von Gierke, H. The Effects of Shock and Vibration on Man. Report of working group No. 39, The Biological Effects of Vibration, AF-NRC, CHABA, Lecture and Review Series, No. 60-3, Naval Medical Research Institute, Bethesda, Md. 8 January 1960.

Hannegan, E. A. Electrical and Electronic Trials of S2F-3 Airplane, Initial Trials Phase (U). Naval Air Test Center, U.S. Naval Air Station, Patuxent River, Md. Project TED No. BIS 21242, WST43-0, Report No. 1, 1961 (CONFIDENTIAL).

Hyman, D. E. An Investigation of the Effect of Various Noise Levels on Performance of Three Mental Tasks, Unpublished Master's Thesis, Purdue University, Lafayette, Ind., June 1950.

Kryter, K. D. The Effects of Noise on Man. Monograph Supplement I, J. Speech and Hearing Disorders, 1950, 1-95.

Kryter, K. D. Human Engineering Principles for the Design of Speech Communication Systems. Operational Applications Office, Air Force Command and Control Development Division, Air Force Research and Development Command, Laurence G. Hanscom Field, Bedford, Mass. AFCCDD Technical Report 60-27, August 1960.

Kryter, K. D. Methods for the Calculation and Use of the Articulation Index, J. Acoust. Soc. Amer., 1962, 34, 1689-1697.

Kryter, K. D., Flanagan, G., and Williams, C. A test of the 20-band and Octave Band Methods of Computing the Articulation Index. Operational Applications Laboratory, Electronics Systems Division, L.G. Hanscom Field, Bedford, Mass. Contract AF 19 (604)-4061, Report No. ESD-TDR-62-4, 1961.

McCord, C. P., Teal, E. E., and Witheridge, W. N. Noise and its Effect on Human Beings. J. American Medical Association, 1938, 110, 1553-1560.

McKelvie, W. B. Weaver's Deafness. J. Larnygology, Rhinology, and Otology, 1933, 48, 607.

MacLaren, W. P., and Chaney, A. L. An Evaluation of Some Factors in the Development of Occupational Deafness. Industrial Medicine, 1947, 16, 109-115.

Military Specification, Acoustical Noise in Aircraft, General Specification for MIL-A-8806 (ASG), 25 October 1956.

Miller, G. A. The Masking of Speech. Psychol. Bull., 1947, 44, 105-129.

Morgan, C. T., Cook, J. S., III, Chapanis, A., and Lund, M. W. Human Engineering Guide to Equipment Design. McGraw-Hill Book Company, New York, 1963.

Petti, L. J. Helmets, Flying and Protective; Evaluation of General Textile Mills, Inc. H-5 Type. U.S. Naval Air Material Center, Naval Air Experimental Station, Aero Medical Equipment Laboratory, Philadelphia, Pa., Rept. No. XG-L-104-855, 1955.

Pollock, K. G., and Bartlett, F. C. Two Studies in Psychological Effects of Noise. Part I. Psychological Experiments on the Effects of Noise. Medical Research Council (Great Britain), Industrial Health Research Board, Report 65, 1932.

Rosenblith, W. A., and Stevens, K. N. Handbook of Acoustic Noise Control. Volume II. Noise and Man. Wright Air Development Center, Air Research and Development Command, USAF, Wright-Patterson AFB, Ohio. WADC TR 52-204.

Stevens, S. S., et al. Part I. The Effects of Noise on Psycho-motor Efficiency. Part II. Noise Reduction in Aircraft as Related to Communication, Annoyance, and Aural Injury. Harvard University, Psychological Laboratory, OSRD Report 274, Dec. 1, 1941.

Strasberg, M. Criteria for Setting Airborne Noise in Shipboard Spaces. Report No. 371-N-12, Department of the Navy, Washington, D.C., July 15, 1952.

Ward, W. D., Glorig, A., and Sklar, D. L. Dependence of Temporary Threshold Shift at 4 kc on Intensity and Time. J. Acoust. Soc. Amer., 1958, 30, 10, 944-954.

Ward, W. D., Glorig, A., and Sklar, D. L. Temporary Threshold Shift from Octave-Band Noise: Applications to Damage Risk Criteria. J. Acoust. Soc. Amer., 1959a, 31, 4, 522-528.

Ward, W. D., Glorig, A., and Sklar, D. L. Relation Between Recovery from Temporary Threshold Shift and Duration of Exposure, J. Acoust. Soc. Amer., 1959b, 31, 5, 600-602.

Webster, J. C., and Klumpp, R. G. Articulation Index and Average Curve-Fitting Methods of Predicting Speech Interference. J. Acoust. Soc. Amer., 1963, 35, 9, 1339-1344.

Woodson, W. E Human Engineering Guide for Equipment Designers. University of California Press, Berkeley and Los Angeles, 1954.

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13. ABSTRACT

Pertinent data on the noise and vibration environments in the S2E and T-39 aircraft, supplied by the Advanced System Development and Structural Dynamics groups of North American Aviation, Inc. are presented and examined regarding the effects of the noise and vibration environments of these two aircraft on crew performance. The nature and scope of the effects of the acoustic noise and vibration environments on human performance are discussed. Both auditory and non-auditory effects are included, and particular emphasis is placed on the speech-interfering characteristics of the noise environment, and also its ability to cause permanent hearing loss. It was found that under some operating conditions the noise levels in the S2E were above specification limits, and that even with a protective helmet, the noise levels in the S2E were sufficiently high to cause some permanent hearing loss.